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An Unwelcome Guest in China

A Pine-Feeding Mealybug

By Jianghua Sun, Gary L. DeBarr, Tong-Xian Liu, C. Wayne Berisford, and Stephen R. Clarke

This story began in January 1988. Two business representatives from the Seed Company of the Ministry of Forestry, People's Republic of China, visited the Southern Seed Company in Baldwin, Georgia, during a seed-buying trip. Just before leaving, they collected 70 scions from slash pines *(Pinus elliottii)* in a second-generation seed orchard.

No quarantine restrictions exist for plant material leaving the United States, and the scions unfortunately were not subjected to the normal quarantine procedures required by the Chinese Animal and Plant Quarantine Law. Instead, they were shipped directly to Hongling Seed Orchard in Taishan City, Guangdong Province *(fig. 1, p. 28)*, in southern China. This 111-hectare orchard of clonal material was established in 1964 with 38 superior slash pines from the United States (Kellison et al. 1982). The imported scions, inadvertently carrying the pine-feeding mealybug *(Oracella acuta)*, were immediately grafted onto slash pine root stock and almost all survived. (During the winter months, the tiny mealybug crawlers—first-instar nymphs—are located between the pine needles beneath the needle fascicles; this probably explains how they entered China undetected.)

Chinese laborers spray insecticides on slash pines in the Hongling Seed Orchard to eradicate Oracella acuta.

Vegetative propagation was continued in 1989. Through repeated graftings, 2,460 new scions were obtained from the original cuttings. The newly grafted trees covered a planting area of 12.4 hectares.

The first sign of trouble appeared in May 1990, when a heavy growth of sooty mold was observed. Accumulations of sooty mold are usually associated with large populations of sucking insects such as aphids, whiteflies, scale insects, or mealybugs. These insects produce copious amounts of honeydew, a nutrient-rich excretion that promotes prodigious fungal growth. Inspections in early June 1990 revealed large numbers of an unknown mealybug on the scions of the newly grafted trees and on older trees nearby.

The provincial government asked China's forest entomologists and scale insect systematists to identify the pest, determine its origin, and recommend eradication or control procedures. Local authorities initially speculated it might be *Pseudococcus pini* (=*Crisicoccus pini*), a mealybug species native to Japan. Specimens were sent to Yang Pinglan, an authority on scale insects at the Shanghai Institute of Entomology. In the summer of 1990, Yang requested assistance from Tong-Xian

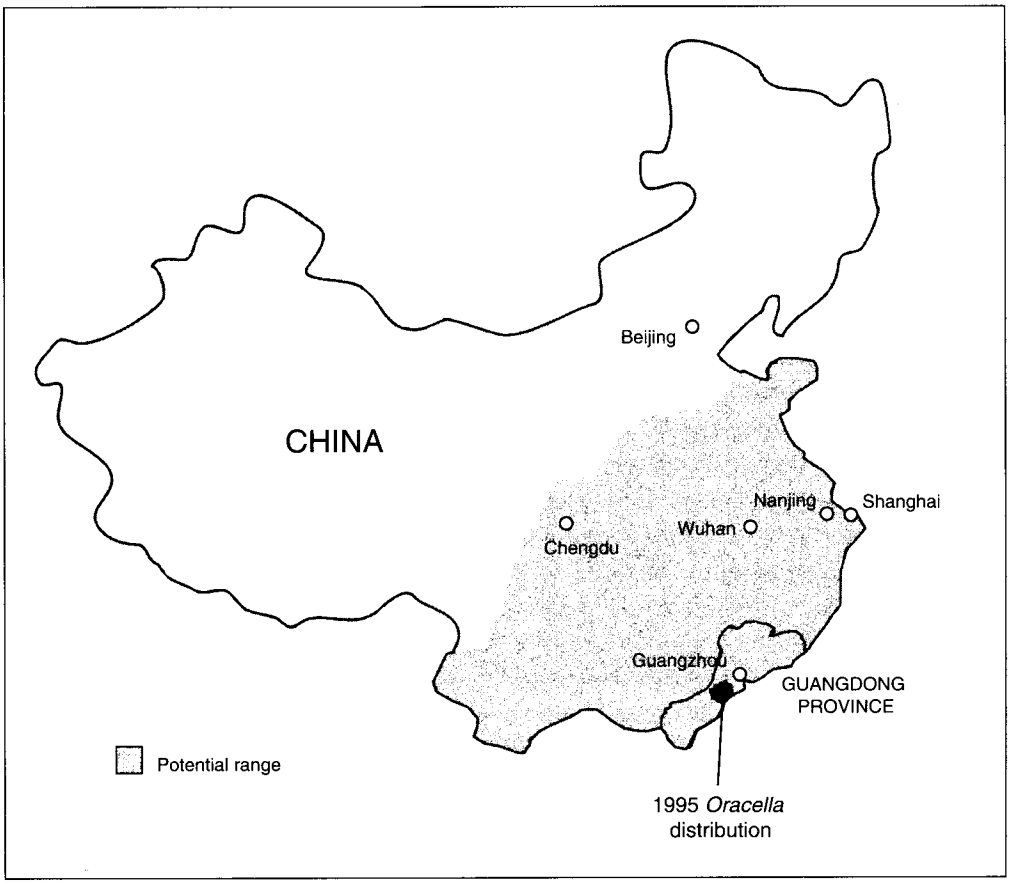


Figure 1. Current distribution and potential range of* Oracella acuta *in China.

Liu, a postdoctoral student at the University of Georgia, in identifying and providing ecological and biological information on "an unknown mealybug introduced from Georgia into Guangdong Province." Extensive communications ensued.

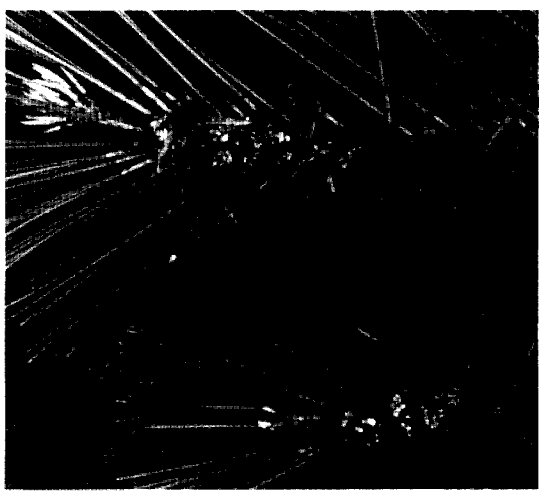
Finally, in spring 1991, Yang sent specimens from infested pine trees to Liu and to D.R. Miller, a mealybug authority with the USDA Agricultural Research Service, Insect Identification and Biological Control Laboratory, Beltsville, Maryland. The mealybug was identified as *O. acuta* (Yang 1991), and a field visit by G.L. DeBarr in July 1992 confirmed the presence of *O. acuta* in China, as well as the threat to seed production in the Hongling Seed Orchard and to extensive pine plantations of southern China (DeBarr 1992).

The Mealybug in the United States

Oracella acuta, presumed to be native to North America, is found throughout the southeastern United States. Lobdell first described it in 1930 as *Pseudococcus acuta* from pines (*Pinus* spp.) in Mississippi. Later, Ferris (1950) described the biology of the mealybug and moved it to the genus *Oracella.* Clarke et al. (1990a) provided a more detailed account of its biology. Although it occurs on slash pine, longleaf pine *(P. palustris),* Virginia pine *(P. virginiana),* and shortleaf pine *(P. echinata),* its primary host is loblolly pine *(P. taeda)* (Johnson and Lyon 1988; Clarke et al. 1992).

O. acuta is the only pine-infesting mealybug known to produce "resin cells" that cover the females. These characteristic cells are attached to twigs near the needle base. They protect the females from attacks by predators and shield them from insecticide treatments. In the Southeast, the mealybug produces four and sometimes five generations per year in loblolly pine seed orchards (Clarke et al. 1990a). Crawlers spend the winter between the needles in the fascicles or under old resin cells formed by females of the previous generation.

In March, when new shoots expand, the crawlers feed on the new growth. Shoot tips just below the terminal bud are the preferred feeding site, but some crawlers settle at the inner base of the needle fascicles. Females, about 2 to 3 millimeters long, secrete a whitish resinous material used to construct the resin cells. Egg production inside these cells begins in mid-April. Crawlers hatch after a few days. Males of the overwintering (first) generation are usually wingless, whereas males of subsequent generations have wings. All females are wingless. Thus, most natural dispersal is via wind-blown crawlers.



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These slash pine shoots are encrusted with resin cells produced by* Oracella acuta. *The cells protect the females from predators and insecticides.

O. acuta is common in natural stands and plantations but is seldom a pest in the southeastern United States. A rich and effective complex of natural enemies, comprising small parasitic wasps and predacious insects, normally keeps mealybug populations low and prevents serious damage *(fig. 2).* Clarke et al. (1990a; 1990b; 1992) observed three parasitic wasps—an encyrtid

(Acerophagus coccois), a platygastrid (*Allotropa* spp.), and a signiphorid (*Chartocerus* spp.)—along with larvae of two predacious species of cecidomyiid flies.

The outbreaks that sometimes occur in the Southeast have been associated with multiple applications of pyrethroid insecticides used to control cone and seed insects in seed orchards (Nord et al. 1985) or pine tip moths (*Rhyacionia* spp.) in Christmas tree plantations. The two primary factors that contribute to outbreaks are the relatively low toxicity of pyrethroid insecticides to the crawlers (Clarke et al. 1988) and the destruction of natural enemies by repeated insecticide applications (Clarke et al. 1990b, 1992).

Host Damage Comparisons

For several decades, the Chinese government has undertaken a massive tree-planting program (Dickerman et al. 1981). Exotic pines such as loblolly pine, slash pine, and Caribbean pine *(P. caribaea)* and native Masson pine *(P. massoniana)* were used to afforest vast areas in the southern and central provinces. This afforestation has provided the mealybug with an almost limitless supply of suitable hosts, particularly since many of the plantings are on poor or depleted sites.

Slash pine, introduced into China from the United States more than 40 years ago, has been planted extensively in the southern provinces (Kellison et al. 1982). Slash pines of all ages are infested by the mealybug, but the most severe damage occurs in high-density, 7- to 10-year-old plantations. Damage currently is most severe on China's slash pine, but even greater damage could occur if the infestation spreads north to plantations of loblolly pine, the mealybug's preferred host in the United States. Damage to Masson pine and Caribbean pine has been much lighter, with little accumulation of sooty mold.

Mealybug densities on slash pine in China exceed those observed on trees in the United States, even in intensively managed Christmas tree plantations or seed orchards treated with pyrethroid insecticides. In China, the mealybug has four or five overlapping generations per year (Xu et al. 1992). Overwintering crawlers become active in late March and adults appear in early April, with peak egg-laying in early May. Each first-generation female lays an average of 182 eggs. Second-generation females lay an average of 113 eggs. The hatch rate is 90%. In addition, conifers growing beyond their natural range may be under greater stress and thus more susceptible to pests than those growing under optimal conditions within their normal range of distribution (McClure 1985a, 1985b).

In the United States, most pitch cells are found on a short section of the shoot just below the buds. In contrast, adults and crawlers completely cover needles and shoots on infested branches in China. Feeding at the base of old needles causes copious resin flow, and the needles turn brown and drop off. Loss of old needles can reach 70 to 80% on severely infested trees (Xu et al. 1992; Pan et al. 1994). Newly hatched crawlers (several dozen to a few hundred) congregate on new succulent shoots. This feeding causes stunted needles and produces shoots with a "foxtail" appearance. These shoots later wither and die. Secondary buds develop when the apical shoots are killed, causing crooked stems and branches.

Copious amounts of honeydew excreted by the mealybugs often cause rapid growth of a thick layer of sooty mold on both shoots and needles, severely reducing photosynthesis. Su et al. (1995) reported that infested slash pines exhibited a reduction of 38% in photosynthesis, 25% in shoot growth, and 24% in tree height growth over a three-year period. Severely weakened trees are susceptible to attacks by other native insects, such as the Masson pine caterpillar *(Dendrolimus punctatus)* and pine bast scale *(Matsucoccus matsumurae)* (McClure et al. 1983). Several instances of these pests on mealybug-infested trees have been observed, but their combined impact is unknown.

Slash pine cones in the Hongling Seed Orchard are also affected. Cones are smaller than normal, and many are deformed and crescent-shaped. Although seed production is reduced, the amount has not been quantified (Xu Jiaxiong, pers. commun.).

Potential Dispersal Range

The status of the mealybug as a major pest in China is steadily increasing due to its rapid dispersal *(fig. 1)*. Scale insects and mealybugs are notorious invaders of new territories, and populations develop rapidly when there is more than one generation per year (Rosen and DeBach 1979). The tropical climate of Guangdong Province permits *O. acuta* activity during most of the year. Females can tolerate up to 22 hours of high tempera-

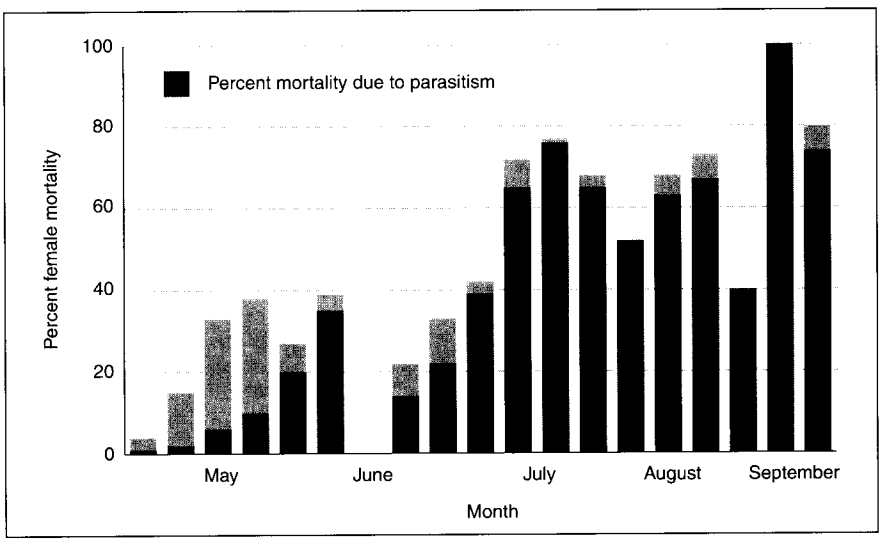

Figure 2. Mortality and parasitism of female* Oracella acuta *in a loblolly pine seed orchard in Bulloch County, Georgia. Source: Clarke et al. 1990a.

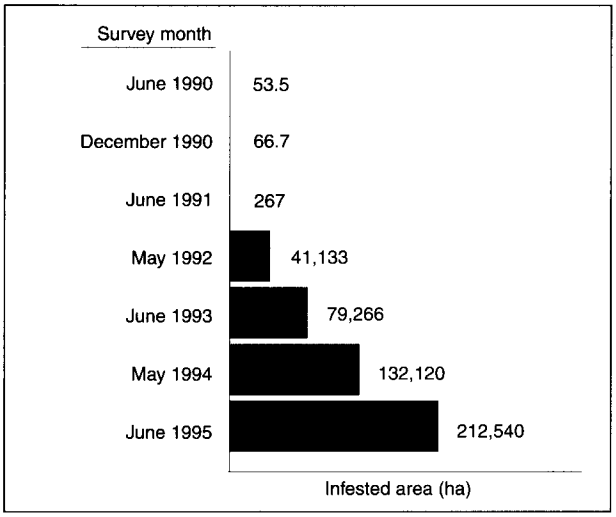

Figure 3. Hectares of slash pine plantations infested by **Oracella acuta** *in China since May 1990.*

tures (40° C) and may live for 6 days without feeding (Pang and Tang 1994). The primary means of dispersal is wind-blown crawlers, but infested pine or other materials can also be transported to uninfested areas.

Despite containment efforts, new infestations are discovered every year, and the infested area has increased exponentially *(fig. 3)*. Xu et al. (1992) reported an average dispersal distance of 17 kilometers/year since 1990, but the 63-kilometer dispersal distance in 1995 exceeded that of any previous year. Dispersal direction and distance are closely related to the prevailing spring and early summer winds. Because most blow from the southeast, dispersal generally occurs to the north and northwest. Invasions to the east and southeast are also slower because these areas are mainly farmland, with only scattered forests. At the current rate, *O. acuta* will soon invade slash pine plantations in the western part of Guangdong Province and loblolly pine plantations in the northern portion.

Slash pine plantations extend from latitude 35°5'N (Pinba County, Shandong Province) south to latitude 18°30'N (Lingshui County, Hainan Province). Loblolly pine grows south of the Changjiang (Yangtze) River. Each year, additional plantations of both species are established. Because this region of China lacks natural physical barriers, such as mountains or lakes, rapid dispersal will probably continue. In fact, this exotic pest may pose an even greater threat to more northerly loblolly pine plantations, where conditions are similar to those of the mealybug's natural range in the United States *(table 1)*.

The best niche for the mealybug may be along a line from Shanghai through Nanjing and Wuhan to Chengdu *(fig. 1)*, where the latitude is similar to that of central Georgia (Zhou et al. 1994). The mealybug also occurs in Maryland, which has a minimum temperature of –20° C. Such low-temperature tolerance suggests dispersal is possible even further north in China.

The high fecundity, hatch rate, temperature tolerance, and near absence of natural enemies (Tang 1994) may explain *O. acuta*'s rapid spread. Because dispersal will probably continue, the Guangdong Provincial Government has listed *O. acuta* as a quarantine pest, and the Chinese Ministry of Forestry considers it one of the nation's eight major forest pests.

Table 1. Comparison of conditions for *Oracella acuta* in the United States and the People's Republic of China.

	Range in the United States	Potential range in China
Latitude	25° N to 40° N	18°3' N to 38° N
Mean January temperature (°C)	–1.1 to 21.1	–4.2 to 13.3
Mean July temperature (°C)	15.0 to 32.2	26.5 to 28.4
Mean January rainfall (cm)	4.1 to 5.0	0.3 to 5.2
Mean July rainfall (cm)	5.0 to 20.0	12.8 to 19.6
Host pines	*P. taeda*	*P. taeda*
	P. echinata	*P. massoniana*
	P. virginiana	*P. caribaea*
	P. elliottii	*P. elliottii*
	P. palustris	*P. thunbergiana*

Source: Zhou et al. 1994.

Control Attempts

Soon after its discovery in 1990, Chinese forest entomologists attempted to eradicate the pest at the Hongling Seed Orchard using insecticides that had been effective against two similar exotic pests, a pine needle scale *(Hemiberlesia pitysophila)* and the pine bast scale. Insecticides were sprayed, injected, or applied as aerosols. When these methods failed, workers cut and destroyed infested branches. Eventually, the entire trees were cut and burned. All these early eradication attempts failed.

In 1992, the Forestry Department of Guangdong Province and the Ministry of Forestry funded continuing studies to investigate *O. acuta* biology, ecology, occurrence, dispersal, population dynamics, and control. Of eleven insecticides screened, the most effective were diesel oil and pine resin emulsions containing rotenone and deltamethrine (Pan et al. 1994). Tests of two bioinsecticides, *Cladosporium cladosporioides* and *Verticillium lecanii*, suggested possible usefulness in Guangdong Province, where the humidity is usually high.

Chinese scientists have made extensive efforts to find native natural enemies for the exotic mealybug in China, particularly seeking parasitoids in slash pine stands with old infestations. The introduction of a platygastrid, *Allotropa* spp. (an effective parasite for *Pseudococcus pini* on pine trees in Chongqin, Sichun Province) was unsuccessful. A predacious coccinellid, *Cryptolaemus montrouzieri*, showed some promise in regulating populations (Tang 1994). However, an intensive two-year search has revealed no effective native parasites in Guangdong or the surrounding provinces (Tang 1994).

None of the control measures tested effectively reduced outbreaks or prevented mealybug spread. To check the

dispersal rate and lessen potential damage, a new approach was required.

Introduction of Parasites

As is often the case, *O. acuta* arrived in China without its associated complement of natural enemies. Although host susceptibility and natural conditions in Guangdong are contributing factors, the absence of parasites and predators is probably the main cause of rapid expansion in the mealybug's range. A general principle of biological control for an exotic pest is the introduction of natural enemies from its native country. For example, when the cottony cushion scale *(Icerya purchasi)* entered the United States from Australia in the late 1880s, it threatened to destroy California's citrus industry. Rapid and permanent control was achieved with an Australian predator, *Rodolia cardinalis* (Clausen 1936).

Each year, natural enemies are introduced to control about 40 pest insects worldwide. The average success rate is 15%, and it is 60% for the control of scale insects or mealybugs (Pu 1987). This indicates mealybugs may be more amenable to classical biological control than other pests. One example is the recent successful introduction of a parasitoid *(Coccobuis azumai)* from Japan to control the exotic pine needle pest, hemiberlesian scale, a species native to Japan and Taiwan (Pan et al. 1993). This scale invaded Guangdong Province from Hong Kong and Macau in 1982 (Pan et al. 1987; Wilson 1993) and spread at a rate of 80,000 hectares per year. In 1986, a group of Chinese forest entomologists discovered its dominant parasitoid in Okinawa. After extensive study and culture in the laboratory, *C. azumai* was released into Guangdong Province in 1989. Now established on more than 250,000 hectares of forests, it maintains the scale populations at low levels (Pan et al. 1993).

A cooperative effort involving the Chinese Ministry of Forestry, the USDA Forest Service, and the University of Georgia to introduce the natural enemies of *O. acuta* into China from the southeastern United States is being conducted. In 1995, five shipments of parasites were sent to a quarantine facility in China.

Conclusions

Since its introduction and establishment in Guangdong Province, *Oracella acuta* has become a destructive pest of exotic slash pines. It spread exponentially and by June 1995 occupied 212,540 hectares in southeastern China. The mealybug will probably continue to disperse rapidly. However, Chinese and American experts have high hopes that natural enemies from the southeastern United States will slow the rate of spread and provide natural regulation. We also hope this is only the beginning of a long and mutually beneficial cooperative effort by scientists in China and the United States to reduce the negative effects of exotic pests.

The introduction of *O. acuta* into China illustrates the ease with which unwanted organisms can be transported inadvertently from one region to another. It also demonstrates that forest insects that are innocuous in their native habitats can create serious and costly problems when introduced into countries and ecosystems that lack their associated biological constraints. As our world enters an era of instant communication, unrestricted travel, and a global economy, only constant vigilance and cooperation among nations will prevent and control an increasing number of unwelcome guests. JOF

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